Radiative Properties of Biological Surfaces

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INTRODUCTION

The radiative heat transfer phenomenon that takes place in many biological materials is not well understood. For example, the excellent insulation characteristics of arctic animals have led researchers[1,2] to study the effects of radiation heat transfer. The majority of previous research has focused on the bulk radiative properties of arctic animal fur in the ultraviolet range (UV). However, we feel that new insight will be obtained by extending this research into the infrared range (IR) where most of arctic animal radiative heat loss occurs. Advances at the ALS facility have made it possible to measure radiative properties at sub-hair dimensions which will aid in understanding how the pelt as a whole functions. The results from these measurements will enable us to determine the basic radiative properties of the hairs and permit us to determine the radiation heat transfer.

METHODS

The radial radiative reflectance and transmittance properties of polar bear hairs were measured using the scanning FTIR available at Beamline 1.4.3 at the ALS. The reflection measurements were made using a gold slide. The 10 micron IR spot was focused at approximately the hair centerline, and a point scan was taken at that location. The results of the reflectance versus wave number were then plotted. These reflectance values were then compared to a background scan of the gold slide and adjusted to show the percent reflection values versus wave numbers. (The percent values are solely a function of the hair, as opposed to the hair *and* the slide.) Transmission measurements were made using a similar method, except that the polar bear hair was mounted across an open space. The thickness of each hair was also recorded. In addition to this, experiments were also completed to determine if the above results could be reproduced. This involved taking a transmittance measurement at a specific point, followed with the identical measurement taken at the same point.

Measuring the axial reflectance will be similar to the radial measurement, with the exception of the orientation of the hair. This will require mounting several hairs in a fixative, such as a hard resin, and then using a microtome to slice the hair. They will be placed vertically on a slide, with the beam focused at the gold slide surface. A point scan will then be taken across the hair centerline. The axial transmission will be similarly mounted except that the array of the axially oriented hairs will be fixed to a slide transparent in the IR.

RESULTS AND DISCUSSION

The results show a measurable transmittance that can be utilized in conjunction with reflectance experiments to ultimately determine the emissivity of the hair using Beer's law. The plots generated from the experiments confirm that the values of the percent transmissivity and reflectivity drop significantly in the infrared range of light. In addition to this, a trend emerges when the averaged percent values of hairs of similar thicknesses are plotted versus the thickness of the hair. It can be seen that as the hair grows thicker the percent transmissivity and reflectivity values decrease. However, many more data points must be taken before a clear relationship can be determined.

The reproducibility tests revealed that the experiments could give significantly different values for the percent transmissivity and percent reflectivity even though they are taken at the same location. Such disparity in these results suggests that the scanning process may be affecting the properties of the hair. It is believed that the energy from the beam may cause a denaturation of proteins in the hair, thus affecting the radiative properties. Further reproducibility experiments will be made with a significant of time allowed between measurements for cooling of the hair. For completeness we note that specific vibrational modes to map out the different compositions of different locations within a hair may also have to be considered in our research.

CONCLUSION

In order to fully understand the radiative properties of polar bear hair, and arctic animal hair in general, it is necessary to collect further data using the scanning FTIR at the ALS. It is only then that we can determine the correlation between hair thickness and radiative properties, as well as the basic radiative properties of the hairs that will permit us to determine the radiation heat transfer.

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